AERONOMY AND ASTROPHYSICS

After hours of delay, the winds shifted enough to launch the Long Duration Balloon at 12:30 a.m. on 21 December 2001. The 5,000-pound, high altitude balloon will circle Antarctica twice while recording atmospheric conditions that could provide clues to the galaxy's history and composition. *(NSF/USAP photo by Melanie Conner)*

The polar regions have been called Earth's window to outer space. Originally, this term applied to dynamic events like the aurora, staged as incoming solar plasmas encountered the Earth's geomagnetic fields. Its unique properties create a virtual screen of the polar upper atmosphere on which the results of such interactions can be viewed (and through which evidence of other processes can pass). During the mid-1980s, Earth's window was extended to refer to the "ozone hole" in the polar atmosphere. As scientists have verified an annual loss of ozone in the polar stratosphere, a window previously thought closed (stratified ozone blocking the Sun's ultraviolet rays) is now known to "open," consequent to chemical cycles in the atmosphere.

For astronomers and astrophysicists, the South Pole presents unique opportunities. Thanks to a minimum of environmental pollution and anthropogenic noise, the unique pattern of light and darkness, and the properties of the geomagnetic force field, scientists staging their instruments here can probe the structure of the Sun and the Universe with unprecedented precision. Studies supported by the Aeronomy and Astrophysics program explore three regions:

- **The stratosphere and the mesosphere:** In these lower regions, current research focuses on stratospheric chemistry and aerosols, particularly those implicated in the ozone cycle.

- **The thermosphere, the ionosphere, and the magnetosphere:** These higher regions derive many characteristics from the interplay between energetically charged particles (ionized plasmas in particular) and geomagnetic/geoelectric fields. The upper atmosphere, particularly the ionosphere, is the ultimate sink of solar wind energy transported into the magnetosphere just above it. This region is energetically dynamic, with resonant wave-particle interactions and joule heating from currents driven by electric fields.

- **The galaxy and the Universe beyond, for astronomical and astrophysical studies:** Many scientific questions extend beyond the magnetosphere, including a particular interest in the Sun and cosmic rays. Astrophysical studies are conducted primarily at Amundsen-Scott South Pole Station or on long-duration balloon flights launched from McMurdo Station. The capability of such balloons is expanding dramatically.

All research projects sponsored by this program benefit from (indeed, most require) the unique physical conditions found only in the high latitudes, yet their ramifications extend far beyond Antarctica. High-latitude astrophysical research contributes to the understanding of Antarctica's role in global environmental change, promotes interdisciplinary study of geosphere/biosphere interactions in the middle and upper atmosphere, and improves understanding of the critical processes of solar energy in these regions. Life exists in a balance on Earth because of numerous chemical and atmospheric phenomena that have developed in the specific atmosphere of this 4.6-billion-year-old spinning planet in orbit 149,637,000 kilometers from a middle-sized, middle-aged star. The 20th-century expansion of traditional astronomy to the science of astrophysics, coupled with the emerging discipline of atmospheric science (see also the Ocean and Climate Systems program), is nowhere better exemplified than in Antarctica.

AMANDA-Antarctic muon and neutrino detector array.
Robert Morse, University of Wisconsin.

The AMANDA project takes advantage of unique polar conditions to discover and probe the sources, both inside our galaxy and beyond, of the shower of very-high-energy neutrinos descending on (and usually passing through) the Earth. Neutrinos are elementary particles believed to have very little or no mass and no electrical charge. Coursing through the universe, they can take any of three forms and interact only rarely with other particles. Thus they arrive on Earth with potentially unique information about where they may have originated. They could be diffuse (made up of contributions from many active galactic nuclei) and may even be an indicator of the decomposition of the mysterious dark matter now believed to dominate the Universe. Or they could be single sources, such as supernova remnants, rapidly rotating pulsars, the gas around black holes, neutron stars, or individual blazars.

AMANDA is the largest detector of neutrinos in the world. During the past 5 seasons, the installation of over 600 photomultiplier tubes [embedded between 1 and 2 kilometers (km) into the ice and oriented downward] has established a natural detector of Cherenkov radiation in the ice. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) High-energy neutrinos with enough energy to pass through the Earth's mass may collide with an atomic nucleus in the ice or rock near the tubes. Such collisions produce a distinctive eerie blue glow, which the basketball-sized glass tubes can detect for up to several hundred meters through the clear ice.

Neutrino astronomy has previously been limited to the detection of solar neutrinos, plus one brief, spectacular burst from the supernova that appeared in the Large Magellanic Cloud in February 1987 (SN-1987a). In recent years, new sources of high-energy gamma rays have been discovered, among them Mrk-421, which was seen by the National Aeronautics and Space Administration's Compton Gamma Ray Observatory and the Mount Hopkins Observatory. AMANDA is designed to study just such objects, which are believed to emit copious numbers of high-energy neutrinos. Now that first-generation detectors such as AMANDA have been enhanced (the array may one day number 5,000 tubes strung on 80-some cables within 1 cubic km of ice), neutrino astronomy would appear to be on the verge of detecting high-energy particles that carry information from the outer edges of the universe. (AA-130-O; NSF/OPP 99-80474)

Advance thin ionization calorimeter (ATIC) science balloon payload.
John P. Wefel, Louisiana State University-Baton Rouge.

The advance thin ionization calorimeter (ATIC) balloon experiment is designed to use the National Aeronautics and Space Administration's Long-Duration Ballooning program for a series of antarctic balloon flights (each 10 to 14 days long) to investigate the composition and energy spectra of galactic cosmic rays (GCR) at the highest energies accessible from balloon platforms, the region up to ~1014 electronvolt (eV). If supernova remnants are, as widely believed, the cosmic accelerators for the GCR, it is in this high-energy region that we anticipate observing effects of the acceleration process.

The ATIC experiment, weighing 1,360 kg and consuming 400 watts of power, consists of three major detector systems: (a) a detector to measure the particle charge; (b) a three-layer, crossed scintillator strip hodoscope, interspersed within a carbon target, to measure the trajectory of the particle; and (c) a fully active bismuth germanate scintillation calorimeter to measure the energy of the hadronic cascade initiated by particle interactions in the carbon target. The individual detectors are read out with application-specific integrated circuit devices.

Previous pioneering experiments have indicated differences in the spectra of hydrogen, helium, and the heavier nuclei, leading to an energy-dependent composition. In addition, the "all-particle" GCR spectrum and composition, as measured by ground-based air shower arrays, show indications of changes in the energy regime approaching the well-known spectral "knee" at 1015-1016 eV. Our goal is to apply new experimental techniques to the study of these very-high-energy particles to verify previous reports and to search for the behavior expected from the supernova remnant acceleration process. (AB-143-O; NASA grant)

Long-duration balloon project.
William Stepp, National Aeronautics and Space Administration/National Scientific Balloon Facility.

As a means of high-altitude exploration, free-flying balloons have many advantages over satellites. Balloons remain in a specific location much longer, cost little to launch, and are designed to return their instruments safely to Earth. Balloons have been flying for two centuries, but until recently were limited by how long they could stay aloft. The latest scientific balloons, deployed from the National Scientific Balloon Facility (NSBF) in Palestine, Texas, are able to fly missions of 100 days or longer.

The current NSBF effort in Antarctica, known as the long-duration balloon (or LDB) program, launches high-altitude balloons carrying scientific payloads into the stratosphere. Many important scientific observations in fields such as hard x-ray/gamma ray and infrared astronomy, cosmic rays, and atmospheric studies have been made from balloons. (AB-145-O; NASA)

Boomerang-Long-duration balloon (B2K): A balloon-borne measurement of polarization in the cosmic microwave background.
John Ruhl, University of California-Santa Barbara.

Cosmic microwave background radiation (CMBR), which originated in the "big bang," is a relic left over from the early days of the Universe. The variations in the brightness on the sky of the CMBR carry the imprint of the distribution of matter about 300,000 years after its creation, and the linear polarization of the CMBR can provide information from even earlier times: that is, just a fraction of a second after creation.

We continue to analyze data gathered in 1998 from a long-duration balloon flight of Boomerang (a millimeter-wave sensitive telescope designed to image CMBR). As we progress, the analysis has larger sky coverage and continues to refine our measurement of the CMB angular power spectrum. The result is better constraints on the cosmological parameters. We are preparing for a second flight of this instrument in December 2002 to measure the polarization of the CMBR. Last year, we conducted successful integration tests at the National Scientific Balloon Facility, but a problem with detector construction has held up our deployment to Antarctica.

The new detectors that have been developed have displayed the target thermal and noise properties and have demonstrated good polarization properties. In addition, the two-color photometers have demonstrated excellent polarization properties as well. This second flight should add significantly to our knowledge about CMBR and the early days of the Universe. (AB-148-O; NSF/OPP99-80654)

The operation of an extremely-low-frequency/very-low-frequency radiometer at Arrival Heights, Antarctica.
A.C. Fraser-Smith, Stanford University.

Since it was discovered in the 1930s that natural phenomena emit the lowest form of electromagnetic energy (radio waves), the field of radio astronomy has joined the scientific effort to analyze both atmospheric and extraterrestrial signals. The extremely-low-frequency/very-low-frequency (ELF/VLF) record of data collected by this project at Arrival Heights-chosen because it is unusually free from manmade electromagnetic interference-now extends unbroken for almost 15 years.

The radiometers at McMurdo operate in both the ELF and VLF ranges, monitoring radio noise from natural sources such as thunderstorms. Characterizing the possible sources of radio interference is important for operational purposes. Since thunderstorms generate telltale radio signals, tracking variations in global noise reflects thunderstorm activity and thus can provide information on changes in global climate.

The Arrival Heights site is one of a network of eight such radiometers operated by Stanford University for the Office of Naval Research. (AO-100-O; NSF/OPP 01-38126)

Magnetometer data acquisition at McMurdo and Amundsen-Scott South Pole Stations.
Louis J. Lanzerotti, Bell Laboratories, Lucent Technologies, and New Jersey Institute of Technology, and Al Weatherwax, Siena College.

The magnetosphere is that region of space surrounding a celestial object (such as the Earth or other planets) where the object's magnetic field is strong enough to trap charged particles. Magnetometers have been installed at selected sites in both polar regions to measure changes in the magnitude and direction of Earth's magnetic field. These changes can arise from a number of causes and are often due to magnetohydrodynamic waves in the magnetosphere. The unique climatic conditions in Antarctica permit scientists to view the atmosphere optically (see project AO-104-O) and to correlate such changes in hydromagnetic waves with the optical emissions caused by charged particles that precipitate from the trapped radiation of the Earth into the upper atmosphere.

In this project, we are measuring such variations with magnetometers installed at conjugate sites in both hemispheres: at McMurdo Station and Amundsen-Scott South Pole Station, Antarctica, and (in collaboration with colleagues) at sites in Canada, including Iqaluit (Northwest Territories). The antarctic systems gather unique data related to the coupling of the interplanetary medium into the dayside magnetosphere, including the magnetospheric cusp region. The data also provide insights into the causes and propagation of low-frequency hydromagnetic waves throughout the magnetosphere.

The antarctic magnetometers continue to measure with high reliability the magnitude and the direction of the variations of the field in the frequency range from about 0 to about 0.1 Hertz, with a resolution of about one nanoTesla. In addition to the research involving the conjugate data, these antarctic data are being analyzed in the context of other concurrent data gathered by the six U.S. automatic geophysical observatories that are a part of the polar experiment network for geophysical upper atmosphere investigations (or PENGUIN) program (see project AO-112-O) and data acquired by other nations in the Antarctic. (AO-101-O; NSF/OPP no number)

High-latitude magnetic pulsations.
Mark Engebretson, Augsburg College, and Roger Arnoldy, University of New Hampshire.

The Earth's magnetic field arises from its mass and motion around the polar axis, but it creates a powerful phenomenon at the edge of space known as the magnetosphere, which has been described as a comet-shaped cavity or bubble around the Earth, carved in the solar wind. When that supersonic flow of plasma emanating from the Sun encounters the magnetosphere, the result is a long cylindrical cavity, flowing on the lee side of the Earth, fronted by the blunt nose of the planet itself. With the solar wind coming at supersonic speed, this collision produces a "bow shock" several Earth radii in front of the magnetosphere proper.

One result of this process is fluctuations in the Earth's magnetic field, called micropulsations, which can be measured on time scales between 0.1 second and 1,000 seconds. It is known that magnetic variations can significantly affect power grids and pipelines. We plan to use magnetometers (distributed at high latitudes in both the antarctic and arctic regions) to learn more about how variations in the solar wind can affect the Earth and manmade systems.

We will study these solar-wind-driven variations and patterns at a variety of locations and over periods up to a complete solar cycle. Since satellite systems are now continuously observing solar activity and also monitoring the solar wind, it is becoming feasible to develop models to predict the disruptions caused by such magnetic anomalies. And while our work is geared specifically toward a better understanding of the world and the behavior of its manmade systems, it will also involve space weather prediction. (AO-102-M/S; NSF/OPP 99-09212)

Antarctic auroral imaging.
Stephen Mende, Lockheed Palo Alto Research Laboratory.

Scientists are only beginning to try quantitative studies on the dynamic behavior of the magnetosphere. In the past, detail-oriented explorations with space satellites have enabled them to map the average distribution of magnetospheric energetic particle plasma content. But the dynamics of auroral phenomena-what happens when particles from the magnetosphere precipitate into the atmosphere, producing fluorescence-have been hard to quantify through optical means. Amundsen-Scott South Pole Station is uniquely situated to observe aurora because the darkness of the polar winter permits continuous optical monitoring; at most other sites, the sky becomes too bright near local mid-day.

The aurora can actually be regarded as a two-dimensional projection of the three-dimensional magnetosphere, because particles tend to travel along the magnetic field line. By observing the dynamics and morphology of the aurora, scientists get a reliable glimpse into the dynamics of the region of the three-dimensional magnetosphere associated directly with it. This method relies on knowledge relating the type of aurora both to specific energies of precipitation and to specific regions of the magnetosphere.

We are deploying an intensified optical, all-sky imager (operating in two parallel wavelength channels, 4,278 and 6,300 Angstroms) to record digital and video images of auroras in the winter darkness. These wavelength bands allow us to discriminate between more and less energetic electron auroras and other precipitation. The South Pole Station observations of the polar cap and cleft regions entail measuring auroral precipitation patterns and then interpreting the results in terms of the coordinated observations of magnetic radio-wave absorption images as well as high-frequency coherent-scatter radar measurements.

We expect this work to provide insight into the sources and energization mechanisms of auroral particles in the magnetosphere, as well as other forms of energy inputs into the high-latitude atmosphere. (AO-104-O; NSF/OPP 98-18086)

Extremely-low-frequency/very-low-frequency waves at the South Pole.
Umran Inan, Stanford University.

Atmospheric scientists orient their studies around different strata, or regions, and the boundaries and interactions between these regions are of particular interest. How are the upper atmosphere regions coupled electrodynamically? What can we learn by measuring the energy that is being transported between the magnetosphere and the ionosphere? These are only two of the questions the U.S. Antarctic Program's automatic geophysical observatory (AGO) program is designed to explore. Plasmas occur in the magnetosphere and the ionosphere, and they can be transported and accelerated by a variety of different wave-particle interactions. One important dynamic in this system is particle precipitation that is driven by extremely-low-frequency/very-low-frequency (ELF/VLF) waves. Thus, measuring ELF/VLF waves from the multiple sites of the AGO network provides a powerful tool for remote observations of magnetospheric processes.

This project maintains a system at Amundsen-Scott South Pole Station to measure magnetospheric ELF/VLF phenomena and to correlate the data with measurements made by the AGO system. (AO-106-S; NSF/OPP 99-09872)

Study of polar stratospheric clouds by LIDAR.
Alberto Adriani, Instituto di Fisica dell'Atmosfera, Rome, Italy.

The appearance each spring of the stratospheric ozone hole above Antarctica is driven by chlorine compounds interacting on the surfaces of clouds that formed the previous polar winter; these are known as polar stratospheric clouds (PSC). This interaction is one explanation of why ozone depletion is much more severe in polar regions than elsewhere.

This project uses an optical radar (LIDAR, light detection and ranging) to study the PSC, stratospheric aerosol and the thermal behavior and dynamics of the atmosphere above McMurdo Station. Continuous LIDAR observations provide insight into the formation, evolution, and other peculiar characteristics of these PSC.

Such an observational activity is also performed in the framework of the Network for the Detection of Stratospheric Change (NDSC), a global set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the atmosphere (see www.ndsc.ws on the Internet). McMurdo Station is considered a primary NDSC site for LIDAR observations and for the monitoring of aerosol and clouds in the stratosphere. Such data also provide a complement to the information gained from the balloon-borne instruments of project AO-131-O, and thus collaborative activities are being coordinated with the University of Wyoming. (AO-107-O; NSF/OPP 90-17805)

A very-low-frequency beacon transmitter at the South Pole.
Umran Inan, Stanford University.

This 3-year project to establish and operate a very-low-frequency (VLF) beacon transmitter at the South Pole will measure solar effects on the Earth's mesosphere and lower ionosphere. Relativistic electrons, measured at geosynchronous orbit to have energies of more than 300 kiloelectronvolts, appear to fluctuate in response to substorm and solar activity. During such events, these highly energetic electrons can penetrate as low as 30 to 40 kilometers above the Earth's surface. At that altitude, they can wreak havoc in the atmosphere: they ionize chemical species, create x rays, and may even influence the chemistry that produces ozone.

By comparing how the South Pole VLF signal varies in both amplitude and phase when it arrives at various antarctic stations, the extent of relativistic electron precipitation can be calculated. The transmitter will also produce other data on solar proton events, relativistic electron precipitation from the Earth's outer radiation belts, and the joule heating components of high-latitude/polar cap magnetosphere/ionosphere coupling processes.

VLF data from the South Pole beacon provide a valuable complement to two other efforts: first, to other antarctic upper atmospheric research, such as the automatic geophysical observatory programs and the Southern Hemisphere coherent high-frequency radar Super4 Dual Auroral Network (SUPERDARN) and second, to ongoing satellite-based measurements of trapped and precipitating high-energy electrons at both high and low altitudes. The latter are collected by the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX). (AO-108-O; NSF/OPP 00-93381)

South Pole Air Shower Experiment-2.
Thomas Gaisser, Tudor Stanev, and Timohty Miller, University of Delaware; and Albrecht Karl, University of Wisconsin-Madison.

Cosmic rays consist of protons and other atomic nuclei, accelerated (scientists believe) to high energy levels in such distant astrophysical sources as the remnants of supernovas. As cosmic rays arrive at Earth from space, they interact in the upper atmosphere. The South Pole Air Shower Experiment-2 (SPASE-2) is a sparsely filled array of 120 scintillation detectors spread over 15,000 square meters at the South Pole. This array detects the charged particles (primarily electrons) that are produced by interactions of these very-high-energy cosmic rays.

A nine-station subarray called VULCAN has been constructed to detect the Cherenkov radiation produced high above the ground in the same showers. (Cherenkov radiation is the light emitted by a charged particle moving through a medium at a speed faster than the speed of light within that material, analogous to the shock wave produced by objects moving faster than the speed of sound.) The SPASE-2 array is located less than half a kilometer from the top of AMANDA (the antarctic muon and neutrino detector array) and is designed to complement its neutrino detecting capacity (see project AA-130-O). SPASE-2 has two goals:

First, it is intended to investigate high-energy primary (galactic in origin) cosmic radiation, by determining the relative contribution of different groups of nuclei at energies greater than about 100 teraelectronvolts. This can be done by analyzing coincidences between SPASE-2 and AMANDA. Such coincident events are produced by high-energy cosmic ray showers with trajectories that pass through SPASE-2 (on the surface) and AMANDA (buried 1.5 to 2 kilometers beneath it). AMANDA detects the high-energy muons penetrating the Earth in those same showers for which SPASE-2 detects the low-energy electrons arriving at the surface. The ratio of muons to electrons depends on the mass of the original primary cosmic ray nucleus. The VULCAN detector further permits the calculation of two other ratios that also depend on primary mass in readings from the showers it detects.

Second, it is intended to use the coincident events as a tagged beam. This construction permits us to investigate and calibrate certain aspects of the AMANDA response. This project is performed in cooperation with the University of Leeds in the United Kingdom. (AO-109-O; NSF/OPP 99-80801)

High-latitude antarctic neutral mesospheric and thermospheric dynamics and thermodynamics.
Gonzalo Hernandez, University of Washington.

The South Pole is a unique and interesting spot from which to observe the dynamic motion of the atmosphere. The fact that it is on the axis of the Earth's rotation strongly restricts the types of wave motion that can occur there, compared with sites at lower latitudes. Antarctica attracts atmospheric scientists for many reasons; a primary draw is that neutral winds perforce can only blow across the Earth's rotational axis. This simple condition has a profound influence on the large-scale dynamics of the atmosphere at high latitudes, since only zonal wave-number one mode horizontal motions are possible.

The resulting simplifications may clarify the behavior of the global atmosphere. For example, how do scientists measure the wind speed of the atmosphere? One direct method is by determining the doppler shift of naturally occurring emissions in the upper atmosphere as they flow along at predictable heights. Hydroxyl radicals, for example, are confined to a fairly narrow band near 90 kilometers of altitude.

This study uses a high-resolution Fabry-Perot interferometer (located at Amundsen-Scott South Pole Station) to make simultaneous azimuthal observations of the individual line spectra of several upper atmospheric trace species, especially the hydroxyl radical and atomic oxygen. The observed doppler shift of the emission lines provides a direct measure of line-of-sight wind speed, while the wind field structure can also be derived from these multi-azimuth measurements. In addition, the simultaneously observed line widths provide a direct measurement of kinetic temperature. (AO-110-M/S; NSF/OPP 99-09743)

Riometry in Antarctica and conjugate regions.
Theodore Rosenberg and Allan Weatherwax, University of Maryland.

We propose to continue studying the polar ionosphere and magnetosphere from Antarctica and nominally conjugate regions in the Arctic. High-frequency cosmic noise absorption measurements (riometry) and auroral luminosity measurements (photometry) will form the basis of our investigations, which will involve extensive collaboration with other researchers using complementary data sets.

We will continue to maintain imaging and broadbeam riometers and two-wavelength zenith photometers at South Pole and McMurdo Stations. In addition, we will continue to provide the data acquisition systems at both stations for the common recording of other geophysical data and their dissemination to collaborating investigators. To enhance the usefulness and timeliness of these data, we will maintain a homepage from which the general scientific community can access these antarctic data sets on a daily basis and, by special arrangement, in near real time. Imaging riometer measurements will also be continued at Iqaluit, Northwest Territories, Canada, which is the nominal magnetic conjugate point of South Pole Station.

Our activities will enable us to participate in, and contribute to, several major science initiatives, including the GEM, CEDAR, ISTP/GGS, and National Space Weather programs. A primary focus of our analysis over the next year will be coordinated ground- and satellite-based studies of Sun-Earth connection events. The overall objective is to understand the relevant physical processes that produce the observed phenomena and how they relate to internal and external driving forces (magnetospheric/ionospheric instabilities and solar wind/IMF variations, respectively). From this may emerge an enhanced capability to predict the possible occurrence of events that might have negative technological or societal impacts sufficiently in advance to lessen their effects. (AO-111-M/S; NSF/OPP 00-03881)

Polar experiment network for geophysical upper atmosphere investigations (PENGUIN).
Theodore Rosenberg, University of Maryland-College Park.

Continued progress in understanding the Sun's influence on the structure and dynamics of the Earth's upper atmosphere depends on increasing knowledge of the electrodynamics of the polar cap region and the key role this region plays in coupling the solar wind with the Earth's magnetosphere, ionosphere, and thermosphere. Measurements that are central to understanding include the electric field convection pattern across the polar cap and knowledge of the response of the atmosphere to the many forms of high-latitude wave and particle energy inputs during both geomagnetically quiet and disturbed situations.

The U.S. automatic geophysical observatory (AGO) network, which consists of a suite of nearly identical instruments (optical and radio wave auroral imagers, magnetometers, and narrow- and wide-band radio receivers) at locations on the polar plateau, actively studies the coupling of the solar wind to ionospheric and magnetospheric processes, emphasizing polar cap dynamics, substorm phenomena, and space weather.

When combined with measurements made at certain staffed stations, AGO network data facilitate both large- and small-scale studies of the energetics and dynamics of the high-latitude magnetosphere. The research will be carried out with in situ observations of the geospace environment by spacecraft, in close cooperation with other nations working in Antarctica and in conjunction with studies performed in the Northern Hemisphere. (AO-112-O; no NSF/OPP award number)

Mapping the sound speed structure of the Sun's atmosphere.
Stuart M. Jeffries, University of New Mexico.

We will observe the velocity and intensity signals from the solar surface, using magneto-optical filters tuned to particular solar absorption lines formed in the midchromosphere and near the base of the photosphere, respectively. We will use a time-distance analysis of the high-frequency component of the observed signals to produce detailed maps of the time it takes acoustic waves to travel across the lower part of the solar atmosphere. The travel-time measurements will then be inverted to give maps that will show how the speed of sound changes in the solar atmosphere, both with location and time. These data will provide a stringent test bed for current models of the solar atmosphere and will almost certainly result in major improvements to these models.

The project provides an important first step toward being able to map the acoustic and magnetic properties of the Sun's atmosphere in three dimensions. Such data will be invaluable in our quest to understand how the Sun affects life on Earth. (AO-115-O; NSF/OPP 00-87541)

Auroral dynamics by the all-sky-imager at Amundsen-Scott South Pole Station.
Masaki Ejiri, National Institute of Polar Research, Japan.

The South Pole is a unique platform for observing aurora during the austral winter season. As a point on the Earth's rotational axis, the pole provides a unique vantage to observe the airglow and to discern the characteristics of acoustic gravity waves in the polar region as they vary in altitude and wavelength. Observing aurora continuously over the 24 hours in a day allows us to collect data on

- the dayside polar cusp/cleft aurora (due to the direct entry of the solar wind);
- afternoon aurora that are closely associated with the nightside magnetospheric storm/substorm activities; and
- the polar cap aurora, which depends on the polarity of the interplanetary magnetic field.

Research has shown that these auroras develop from precipitating low-energy particles entering the magnetosphere from the solar wind.

Though data have been gathered at the South Pole since 1965 with a film-based, all-sky camera system, newer technology now produces digital images and permits us to process large amounts of information automatically. Currently, we are using the all-sky-imager, a digital charge coupled device imager monitored and controlled by the National Institute of Polar Research in Japan.

These international collaborations should enhance knowledge of the magnetosphere, the ionosphere, and upper/middle atmosphere physics. The high-frequency radar installations at Halley Bay, Sanae, and Syowa Stations provide the vector velocity of ionospheric plasma over the South Pole. These studies should provide further insight into the physics of the magnetosphere, the convection of plasma in the polar cap, and solar wind effects-specifically dayside auroral structure, nightside substorm effects, and polar cap arcs. (AO-117-O; U.S.-Japanese cooperative project)

Solar and heliosphere studies with antarctic cosmic ray observations.
John Bieber, University of Delaware.

Cosmic rays-penetrating atomic nuclei and electrons from outer space that move at nearly the speed of light-continuously bombard the Earth. Colliding with the nuclei of molecules found in the upper atmosphere, they create a cascade of secondary particles that shower down on Earth. Neutron monitors deployed in Antarctica provide a vital three-dimensional perspective on this shower and how it varies along all three axes. Accumulated neutron-monitor records (begun in 1960 at McMurdo Station and in 1964 at Amundsen-Scott South Pole Station) provide a long-term historical record that supports efforts to understand the nature and causes of solar/terrestrial and cosmic ray variations as they are discerned over the 11-year sunspot cycle, the 22-year Hale cycle, and even longer time scales.

This project continues a series of year-round observations at McMurdo and Amundsen-Scott South Pole Stations recording cosmic rays with energies in excess of 1 billion electronvolts. These data will advance our understanding of a number of fundamental plasma processes occurring on the Sun and in interplanetary space. At the other extreme, we will study high time-resolution (10-second) cosmic ray data to determine the three-dimensional structure of turbulence in space and to elucidate the mechanism by which energetic charged particles scatter in this turbulence. (AO-120-M/S; NSF/OPP 98-16129)

A versatile electromagnetic waveform receiver for South Pole Station.
James LaBelle, Dartmouth College, and Allan Weatherwax, Siena College.

The Earth's aurora naturally emits a variety of low-frequency (LF), MF (medium-frequency), and high-frequency (HF) radio waves that are signatures of the interaction between the auroral electron beam and the ionospheric plasma. Yet some of the mechanisms that generate plasma waves are not well understood. This project focuses on several types of signals detectable at ground level, including auroral hiss, which occurs primarily at very low frequencies but often extends into the LF/MF range, and auroral roar, a relatively narrowband emission generated near or at the second and third harmonics of the electron cyclotron frequency.

We will use a versatile electromagnetic waveform receiver deployed at South Pole Station. Only recently has it been possible to conceive of an inexpensive, versatile receiver of this type for the South Pole. An antarctic location is essential for ground-based observations of LF auroral hiss, because the broadcast bands usually found in the Northern Hemisphere are typically absent in Antarctica. Also, the absence of broadcast bands improves the effectiveness of automatic wave-detection algorithms.

We can use the receiver to address many issues. For example, it has recently been discovered that auroral roar is sometimes modulated at frequencies between 7 and 11 Hertz, a phenomenon called flickering auroral roar. This receiver will allow us to find out how common flickering auroral roar is, the conditions under which it occurs, what the frequencies are, and how the amplitude and frequency vary over time.

Between 15 percent and 30 percent of auroral hiss events are not observable at very low frequencies. The receiver will determine whether LF auroral hiss consists exclusively of relatively unstructured broadband impulses or whether it sometimes displays a fine structure similar to that of auroral kilometric radiation and whistler-mode waves in the same frequency range detected in the lower ionosphere. We will also define and test auroral roar and auroral hiss mechanisms. Despite its extensive application for communications, the LF/MF/HF band has been relatively little investigated as a source of natural radio emissions detectable at ground level.

A complete knowledge of our geophysical environment requires understanding the physics of these emissions. Further, electron beam-plasma interactions analogous to the terrestrial aurora occur in many space physics and astrophysics applications. Often, the electromagnetic radiation emitted by these systems is our only source of knowledge about them. The local auroral plasma provides an opportunity to view some plasma radiation processes at close range. (AO-128-O; NSF/OPP 00-90545)

Effects of enhanced solar disturbances, during the 2000-2002 solar-max period, on the antarctic mesosphere-lower-thermosphere (MLT) and F regions composition, thermodynamics, and dynamics.
Gulamabas Sivjee, Embry Riddle Aeronautical University.

While variations in the Sun's energy affect people in obvious ways by driving the weather and the seasons, there are actually many cycles and variations of deeper interest to science, on scales from seconds to centuries to eons. One of the most basic is the 11-year cycle when the Sun's magnetic poles reverse direction (since reliable observations began, 23 of these have occurred and the last has just recently peaked), and sunspots and other solar activity wax to peak levels. The National Aeronautics and Space Administration is using this opportunity to conduct its TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite study, which will focus on the region between 60 and 180 kilometers above the Earth's surface.

Taking advantage of the timing of both of these events, we will use observations in the visible and near-infrared ranges of upper-atmospheric emissions above South Pole Station to study the heating effects of auroral electrical currents in the ionosphere, as well as planetary waves and atmospheric tides.

As it passes overhead, TIMED will provide data on the temperature, winds, and tides of the Earth's upper atmosphere, especially above the poles. But tracking satellites often have difficulty differentiating between variations in location or time. South Pole ground-based observations will be valuable in sorting out the time-location question. (AO-129-O; NSF/OPP 99-09339)

Measurements of polar stratospheric clouds, condensation nuclei, and ozone during the austral winter and spring.
Terry Deshler, University of Wyoming.

The stratospheric ozone layer provides an essential shield against solar ultraviolet radiation. The discovery in 1985 of large seasonal ozone losses above Antarctica took the world and the scientific community by surprise. Since that time, the cause of this unprecedented ozone loss has been identified, and governmental and commercial controls are in place to reduce the stratospheric chlorine load. However, while the overall cause of these large ozone losses is understood, many details must still be clarified before we can comprehensively model the stratospheric ozone balance. An international experiment to address some of these details will be undertaken from June through October of 2003. This experiment will compare balloon-borne ozone observations from nine antarctic stations (South Pole, General Belgrano II, Dumont d'Urville, Vicecomodoro Marambio, Georg von Neumayer, Rothera, Syowa, Davis, and McMurdo) with several three-dimensional transport models. The balloon releases will be coordinated to sample air parcels previously sampled at another location. Comparing the ozone changes within these air parcels, as they are tracked around the continent, provides an excellent test of our understanding of stratospheric chemistry. Similar experiments have been completed in the Arctic, but this is the first opportunity in the Antarctic.

The observations from McMurdo Station will also add to our database of annual profiles of ozone in late winter and spring. These observations will be completed as stratospheric chlorine levels are peaking and will provide, at a minimum, a basis for detecting the first signs of zone recovery. Such vertical ozone profiles constitute one of the crucial tools needed to observe the first signs of recovery following the decline in stratospheric chlorine. These measurements are archived in the database of the Network for the Detection of Stratospheric Change.

In addition to these ozone observations, we will extend our in situ observations of polar stratospheric clouds (PSCs). PSC instruments provide estimates of the size and concentration of the particles that form in these clouds. Heterogeneous chemistry-which activates chlorine so that it can then destroy ozone-occurs on the surface of such particles. These measurements provide estimates of the surfaces available for heterogeneous chemistry, of the rates of denitrification and dehydration, and of particle composition. We will continue our collaboration with the LIDAR (light detection and ranging) PSC measurements being taken at McMurdo Station (see project AO-107-O). (AO-131-O; NSF/OPP 99-80594)

In-situ measurements of halogen oxides in the troposphere.
Linnea Avallone, University of Colorado-Boulder.

This project includes research into the role of halogen oxides in tropospheric chemistry, as well as the development of two graduate courses-a laboratory experience based on observations of tropospheric trace gases and a professional development seminar-to enhance the current curriculum in atmospheric and oceanic sciences at the University of Colorado.

To investigate the role of halogen oxides in the chemistry of the troposphere, an in-situ instrument employing a low-pressure chemical conversion/resonance fluorescence technique will be deployed in the boundary layer and the free troposphere at various sites, including Niwot Ridge, Colorado; Bremen, Germany; and McMurdo Station, Antarctica. Each site has been chosen because of its unique location and facilities and with the goal of detecting these oxides under a variety of environmental and meteorological conditions. For these activities, the in-situ instrument will be augmented by a meteorological measurement system, which provides data on temperature, pressure, relative humidity, and wind direction and speed, plus an ozone analyzer.

Further, two new courses in the atmospheric and oceanic sciences will be designed and implemented. The first will be an inquiry-based laboratory course for upper-division undergraduates and beginning graduate students. This course will build on the resources available within the campus and surrounding atmospheric sciences communities to acquaint students with the nature and practice of experimental science. In addition, the course will offer an opportunity for students to acquire and improve career skills in teamwork and in oral and written communication.

The second course, a seminar-style professional development class, will be designed to better prepare graduate students for the array of academic and nonacademic jobs available to them after they receive their degrees. This class will expose students to topics such as ethics in research, methods for writing and reviewing papers and proposals, and resources for improving teaching skills. Speakers from industry, national laboratories, community colleges, and so on, will be invited to help students explore the various avenues their careers might take. (AO-132-O; NSF/ATM 98-75829)

The measurement and analysis of extremely-low-frequency waves at South Pole Station.
Marc R. Lessard, Dartmouth College, and James LaBelle, Dartmouth College.

This project aims to detect and record magnetic field fluctuations in the extremely-low-frequency (ELF) range at South Pole Station, specifically auroral ion cyclotron waves, which have been well correlated with flickering aurora. Theory predicts that these waves modulate precipitating electron fluxes, thereby causing the flickering in luminosity emissions. Substantial evidence now supports this theory, although the excitation mechanism responsible for the ion cyclotron waves is somewhat uncertain. Perhaps the most well developed theory suggests that the waves result from an electron-beam instability. In any case, the frequency of the flickering or, equivalently, the frequency of the ground-based observations of ion cyclotron waves can be used to infer the altitude of the excitation mechanism, since the wave frequency depends on the strength of the background magnetic field, which is a known quantity. As such, the information that will be acquired can be used to test models of auroral acceleration mechanisms, as well as study dispersive ELF waves, a type of wave that has been reported in the literature only a few times, but one that may provide important information on substorm onset or, perhaps, the boundaries of open and closed magnetic fields.

A first step is to identify the wave mode and to determine the location and geomagnetic conditions under which these waves can be observed. The equipment used to make these observations consists of an induction coil magnetometer and data acquisition system. The induction coil is a commercially available device, one that was originally designed for geophysical exploration. Data will be returned to Dartmouth College for analysis. (AO-136-O; NSF/OPP 01-32576)

Dynamics of the mesosphere and lower thermosphere using ground-based radar and TIMED instruments.
Susan K. Avery, University of Colorado-Boulder.

This is a propitious time to study a number of atmospheric phenomena, because the 11-year solar cycle recently peaked and because of the National Aeronautics and Space Administration's (NASA's) TIMED (thermosphere-ionosphere-mesosphere-energetics and dynamics) satellite mission (see project AO-129-O). In addition to measurements derived from instruments on TIMED, we are installing a meteor radar at Amundsen-Scott South Pole Station. Concentrating on the dynamics of the mesosphere and lower thermosphere, we are looking at

- the space-time decomposition of wave motions,
- the delineation of the spatial climatology over Antarctica with emphasis on the structure of the polar vortex,

- the dynamic response to energetic events, and interannual variability.

The proposed meteor radar is a very-high-frequency system capable of measuring the spatial structure and temporal evolution of the horizontal wind field over the South Pole. Spatial climatology data will also come from existing ground-based radar at Davis Station, Syowa Station, Rothera Station, and the Amundsen-Scott base.

As NASA's TIMED satellite orbits over the South Pole, wind and temperature data will provide counterpoint and corroborative information. Thus, experiments based both in space and on the ground can be mounted, and data that previously relied on a single source can be better validated. (AO-284-O; NSF/OPP 00-00957)

Global thunderstorm activity and its effects on the radiation belts and the lower ionosphere.
Umran Inan, Stanford University.

Tracking dynamic storms is a challenge, but lightning associated with thunderstorms can provide scientists with an indirect way of monitoring global weather. This project employs very-low-frequency (VLF) radio receivers located at Palmer Station; these are operated in collaboration with the British and Brazilian Antarctic Programs, both of which have similar receivers. All are contributors to the Global Change Initiative.

The VLF receivers measure changes in the amplitude and phase of signals received from several distant VLF transmitters. These changes follow lightning strokes because radio (whistler) waves from the lightning can cause very energetic electrons from the Van Allen radiation belts to precipitate into the upper atmosphere. This particle precipitation then increases ionization in the ionosphere, through which the propagating VLF radio waves must travel. Because the orientations to the VLF transmitters are known, it is possible to triangulate the lightning sources that caused the changes. Once the direction of the lightning source is known, it can be subjected to waveform analysis and used to track-remotely-the path of the thunderstorms.

The data will also be correlated with data from the antarctic Automatic Geophysical Observatory network and will be used by scientists studying the magnetosphere and the ionosphere. (AO-306-P; NSF/OPP 99-10565)

Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
Anthony Stark and Adair Lane, Smithsonian Institution Astrophysical Observatory; Christopher Walker, University of Arizona; James Kooi, California Institute of Technology; and Richard Chamberlin, California Institute of Technology Submillimeter Observatory.

Astronomy is undergoing a revolutionary transformation, where for the first time we can observe the full range of electromagnetic radiation emitted by astronomical sources. One of the newly developed and least explored bands is the submillimeter, at frequencies from about 300 giga-Hertz up into the tera-Hertz range. Submillimeter-wave radiation is emitted by dense gas and dust between the stars, and submillimeter-wave observations allow us to study in unprecedented detail the galactic forces acting on that gas and the star formation processes within it.

The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a 1.7-meter, single-dish instrument that has been operating for 6 years in several submillimeter bands. It has made position-position-velocity maps of submillimeter-wave spectral lines with arcminute resolution over regions of sky that are several square degrees in size. AST/RO provides a valuable complement to the planned arrays, which are inefficient when observing large areas because of their small field of view. AST/RO can observe molecular clouds throughout the fourth quadrant of the Milky Way and the Magellanic Clouds to locate star-forming cores and study in detail the dynamics of dense gas in our own galaxy. AST/RO studies are showing how molecular clouds are structured, how the newly formed stars react back on the cloud, and how galactic forces affect cloud structure. They have also shown that the structure of molecular clouds is affected by their heavy element content and by their proximity to spiral arms, have studied the gradient of heavy elements in the galaxy, and have recently observed deuterated water to better understand the chemistry of water in dense clouds.

Essential to AST/RO's capabilities is its location at Amundsen-Scott South Pole Station. Most submillimeter radiation is absorbed by irregular concentrations of atmospheric water vapor before it reaches the Earth's surface. The desiccated air over South Pole Station allows an accurate intercomparison of submillimeter-wave power levels from locations on the sky separated by several degrees. This is essential to the study of submillimeter-wave radiation on the scale of the Milky Way and its companion galaxies.

We will devote equal effort to three initiatives: large-scale maps of emissions in the Galactic Center and the Magellanic Clouds (these will be made freely available), support of proposals from the scientific community, and installation and use of the detector systems currently under development. (AO-371-O; NSF/OPP 01-26090)

Degree angular scale inferometer: Cosmic microwave background anistropy polarization and fine-scale structure.
John Carlstrom, University of Chicago.

We plan to continue cosmological observations with the degree angular scale interferometer (DASI), which was first deployed at the Amundsen-Scott South Pole Station during the 1999-2000 austral summer. DASI is providing continuous high-quality measurements of the cosmic microwave background (CMB) radiation anisotropy over the critical range of angular scales spanning the first three acoustic peaks in the CMB power spectrum. The data are transferred daily to the University of Chicago, where analysis is keeping pace with the data rate. Plans are to publish the resulting power spectrum by the end of the year.

During the next austral winter, we will use DASI to measure the currently undetected polarization of the CMB anisotropy. The measurements will provide a critical test of the standard theory of the early Universe. The observations will also be done using full Stokes parameters, allowing a measurement of the cross-correlation of total intensity and polarization anisotropy. We will also construct new receiver components to reconfigure DASI from 30 giga-Hertz (GHz) to 100 GHz for intensity and polarization measurements of the fine-scale CMB anisotropy power spectrum. These new capabilities will allow detailed observations of the Sunyaev-Zel'dovich Effect (SZE) in nearby galaxy clusters and allow SZE surveys from massive clusters.

These proposed efforts complement other ongoing and planned CMB experiments with instruments in Chile and at the South Pole. These three instruments can view the same region of the sky and will provide detailed power spectra over this angular range, thereby gathering crucial data for understanding foreground contamination. These three instruments, working together, will allow this essentially unexplored but theoretically important portion of the CMB anisotropy power spectrum to be fully determined.

Outreach and education related to the project will be disseminated and implemented through established structures and mechanisms. These programs, which reach out to local and distant K-12 schoolteachers and students, will use the excitement of exploring our Universe to help attract women and minorities to science. Also, graduate and undergraduate education and research will be integrated into the construction of the instrumentation, as well as the data analysis. (AO-373-O; NSF/OPP 00-94541)

Mapping galactic magnetic fields with the submillimeter polarimeter for antarctic remote observations (SPARO).

Giles Novak, Northwestern University.

The submillimeter polarimeter for antarctic observations (SPARO) maps interstellar magnetic fields by measuring the linear polarization of submillimeter thermal emission from magnetically aligned interstellar dust grains. Interstellar magnetic fields are generally difficult to observe, especially in the dense regions to which SPARO is most sensitive. It is important to study these fields because their energy density is comparable to that of the other physical ingredients that are found in interstellar regions, so they can play important roles in the physical processes that occur there. This program is designed to contribute to our understanding of two general problems in which interstellar gas (and probably magnetic fields as well) has an important role: in the study of the Galactic Center region and star formation.

The study of the super-massive black holes that are found at the centers of many galaxies is motivated in part by our desire to understand the behavior of nature in such extreme environments and in part by the likely influence of these active galactic nuclei on the evolution of galaxies and perhaps of the Universe. Also, magnetic fields in star-forming regions may help support star-forming clouds against gravity, or they may help clouds collapse via angular momentum transfer. The SPARO instrument is operated on the Viper 2-meter telescope at the South Pole. Observations are carried out by personnel who remain there for the 8-month winter when South Pole Station is inaccessible. These observations are complementary to submillimeter polarimetry that is being carried out by larger telescopes at Mauna Kea, but SPARO is much more sensitive to submillimeter emissions because of the exceptionally good atmosphere transmission and the stability of the winter skies over the antarctic plateau.

Therefore, our observations are specifically aimed at (a) confirming SPARO's recent discovery of a large-scale toroidal magnetic field at the Galactic Center, (b) testing a magnetic outflow model for the Galactic Center Lobe, a radio structure possibly tracing gas that has been ejected from the galactic nucleus, and (c) mapping large-scale magnetic fields in a sample of star-forming clouds to study the relationship between the elongated shapes of these clouds and their magnetic fields. (AO-376-O; NSF/OPP 01-30389)

ACBAR: Arcminute cosmology bolometer array receiver.
William L. Holzapfel, University of California-Berkeley.

Advances in detector technology are enabling a revolution in cosmology. Arrays of bolometric detectors on the ground have recently been used to image large regions of the cosmic microwave background (CMB) sky from balloons and are detecting luminous dusty galaxies at high redshift. The arcminute cosmology bolometer array receiver (ACBAR) is a 16-element, 250-micro-Kelvin detector system that was deployed at the South Pole in November 2000 and is designed to be used with the Viper telescope there. ACBAR will image the sky in four bands and thus fill an important niche in angular-scale and frequency coverage between existing millimeter-wave, balloon-borne, and ground-based instruments. These four frequency bands were chosen to take full advantage of the excellent millimeter (mm) and submillimeter atmospheric windows available for observations from the South Pole.

ACBAR is designed to probe the Universe in two distinct ways: First, the measurement of small angular-scale structure in the CMB will complement the large angular scales probed by various satellites and balloon-borne instruments, leading to improved constraints on cosmological models. Second, the imaging and discovery of galaxy clusters with the Sunyaev-Zel'dovich Effect (SZE) will provide a wealth of new cosmological information. ACBAR's broad frequency and angular-scale coverage enable enormous leaps forward in both of these directions. The receiver also serves as a test bed for the detector and optics technology that will eventually fly on the European Space Agency's Planck satellite in 2007.

With this combination of sensitive detectors, high-angular resolution, and broad frequency coverage, ACBAR will be used to advance cosmology research on several fronts. Observations of the CMB provide a glimpse of the Universe at the time when it was only about 300,000 years old. Also, only recently have technological advances made observations of the SZE possible. To separate the thermal and kinematic components of the SZE, observations must be made at several mm-wavelength frequencies. Other experiments are producing detections of the SZE in x-ray-discovered distant clusters. ACBAR will significantly advance these efforts.

This second season of observation will see the analysis and publishing of the results of two previous years of observation. (AO-378-O; NSF/OPP 00-91840)

Wide-field imaging spectroscopy in the submillimeter: Deploying SPIFI on the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO).
Gordon Stacey, Cornell University.

SPIFI (the South Pole imaging Fabry-Perot interferometer) is the first direct detection imaging spectrometer for use in the submillimeter band and was designed for use on the 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) at the South Pole in the far-infrared and submillimeter windows. After having developed and extensively field-tested SPIFI, our primary scientific goals are to

- image the inner regions of the galaxy, in particular submillimeter lines that characterize excitation conditions in the Central Molecular Zone (CMZ), and trace the dynamics of the gas. Questions to be answered are, among others, Can we trace neutral gas flowing through the CMZ? Are there shocks from cloud-cloud collisions in this flow? What is the connection between the CMZ molecular clouds and the circumnuclear ring?

- map the Large Magellanic Cloud and Small Magellanic Cloud in these lines. The low metalicity environment in these dwarf galaxies may mimic that of protogalaxies, so that investigating the interaction between star formation and the interstellar matter in these galaxies is key to understanding the star formation process in the early Universe.

- characterize and map the physical conditions of the interstellar matter in nearby galaxies. These data are unique and will be key to understanding the relationships between density waves, bar potentials, and galaxy-wide star formation.

These projects can be undertaken only with the high sensitivity and mapping capabilities of the SPIFI AST/RO combination. SPIFI is much more sensitive than the best heterodyne receivers, which do not have the sensitivity, or (often) the bandwidth, to detect the broad, weak lines from galaxies, or the spatial multiplexing capability necessary for wide-field mapping projects. We plan to gradually upgrade SPIFI by a factor of 10. We will also make modest optical and cryogenic modifications to SPIFI to improve it in ways important to successful polar operations. The result will be better spatial resolution, with a wider field of view, and a large improvement in system sensitivity. Moreover, the new cryogenic system will require servicing only every 5 days instead of the current 40 hours. This is helpful for outdoor polar operations. This new system also reduces helium consumption (by a factor of 2) and therefore reduces cost. (AO-377-O; NSF/OPP 00-94605)